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Banking Regulation and Banking Crises Probability in European Countries

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ABSTRACT

The **main hypothesis** of the paper was the thesis that banking regulation is intended to minimize the probability of financial instability, including banking crises, which have long-lasting and destructive consequences for the economy. The **practical aim** of this investigation is to explore the impact of banking regulation instruments on the banking crisis probability. Despite a large and growing body of literature that has investigated the role of banking regulation in ensuring financial stability, only a few of them explored the aspect of this problem we are considering, and this constitutes the **scientific novelty** of the research. The **results** confirm the effectiveness of banking regulation in predicting periods of stability in banking systems. Based on the use of **bibliometric analysis** with the software tool VOSviewer v.1.6.10, the main patterns in the theory of banking regulation development have been identified. To conduct an empirical analysis, the author used a database of eleven European countries from 1998 to 2017, whose banking systems had manifestations of a systemic banking crisis. Binary modeling (logit model) was used as a scientific and methodological tool for statistical research. The conducted empirical analysis declared the need to tighten banking regulations in the field of non-performing loan control since it leads to an increase in the banking crisis probability. The results of binary modeling also emphasized the importance of macroeconomic and monetary factors, the neglect of which leads to the vulnerability of banking institutions and, consequently, to banking crises. An important **conclusion** of the analysis is that in order to minimize systemic banking crises, it is necessary to ensure the achievement of the target parameters of the main macroeconomic indicators, expressed in terms of the optimal level of inflation and annual GDP growth. The proposed binary model can be used to further study the causes of a banking crisis, as well as methodological and empirical clarification of the role of banking regulation in the probability of its occurrence.

Keywords: banking regulations; banking crisis; financial stability; systemic risk; monetary policy; bibliometric analysis; VOSviewer; binary modeling; logit model

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INTRODUCTION

Global financial crisis — one of the recent large-scale banking crises — has demonstrated extensive negative effects in the form of falling production and significant social costs. Compared to other financial crises (currency and debt), banking crises are the costliest for a country in terms of total output losses [1–3]. According to calculations Nakatani [4], done for 49 developing countries, the currency crisis causes a 4% drop in GDP, while the cost of banking crises is 6–7% of GDP.

Results of empirical research [5] show that the stability of the banking system ensures the economic sustainability of the country in view of the reduced volatility of value added in the real economy. For example, in countries with more developed financial and institutional systems, bank stability reduces the volatility of value added to a greater extent in sectors of the real economy that have significant external financial dependence. Bank sustainability in countries with weak competition in the banking sector is particularly important to mitigate economic instability. In this regard, theme identification the probability of a system banking crisis is very relevant from the point of view of regulatory policy. Detection of crisis situations, assessment of the effectiveness of regulatory interventions, including actions of central banks aimed at changes in capital

adequacy and liquidity standards, give regulators more time to develop new or amend existing preventive measures

In order to avoid or minimize the devastating effects of further banking crises, financial conditions have been tightened in many countries through banking regulation. Several empirical studies have shown that weak regulation and supervision of banking activities are the factors leading to the crisis [6–11]. Therefore, the countries were significantly affected by the global financial crisis had weaker banking regulation and supervision than those that did manage better the situation during the turbulence crisis [12–14]. For this reason, the issue of the effectiveness of regulatory and supervisory approaches applied in the banking sector in the run-up to the crisis was actively studied in the world scientific literature, including in Russia [15–18] and Azerbaijan [19–21]. Thus, a statistical analysis conducted by M. Cihak et al. [22] showed that the crisis countries had a lower actual capital adequacy ratio, less strict regulation of non-performing loans, and regulators in these countries were unable to require banks to recapitalize, increase their reserves, modify compensation schemes and/or suspend (cancel) management bonuses.

Significant research was also conducted in the area of forecasting banking crises, including in Russia [23, 24]. E.P. Davis and D. Karim [25] has been established Early Warning Systems (EWS) to calculate the probability of bank crises. According to these developments, a significant increase in borrowed financial resources and GDP are predictors of the banking crisis in the country. Based on machine learning, J. Buetel, S. List, G. von Schweinitz [26] also proposed a mechanism for forecasting bank crises, according to which credit expansion, asset price boom and external imbalances are the key warning indicators, require continuous monitoring by financial regulators.

Most existing empirical studies focused on the predictability and spread of financial crises estimate the probability that the banking system will go into crisis based on traditional probit/logit-models.

One of the first research to study the determinants of the occurrence of currency shocks in developing countries based on probit-modeling was conducted by J.A., Frankel and A.K. Rose [27] and make a decisive contribution to the development of the scientific literature on the development of early warning systems for crises. Most subsequent researches examine country-specific causes of financial market turbulence and the resulting financial crisis. Using a multi-dimensional regression logit-model, P. Laina et al. [28] developed a system crisis early warning system for eleven European Union (EU) countries according to which its best precursors are the ratio of loans to deposits and property prices. In later works use alternative modifications of binary estimation methods (logit-model with fixed effects, probit-model with random effects). Thus, the work of B. Gaies et al. [29] shows that the number of banking crises in developing countries decreases as the exchange rate stabilizes, real GDP grows, human capital improves and political institutions improve. Despite research increase, devoted to the study of the determinants of the banking crisis, only a few of them analyze the impact of regulatory policy on the probability of its occurrence [10, 30]. In particular, using data from 65 countries in the period 2000–2016, R. Nakatani [31] found that changes in the loan-to-value ratio (LTV) have a positive impact on the probability of a bank crisis in countries with inflation targeting, floating exchange rate regimes and/or lack of capital controls.

BIBLIOMETRIC ANALYSIS OF EXISTENT LITERATURE

Despite the significant growth of researches, aimed at analyzing the role of banking regulation in financial stability, few empirical studies have analysed its impact on the probability of a banking crisis. On the basis of the use of bibliometric (VOSviewer v.1.6.10)

analysis, which is widely spread in the scientific sphere [32–35], the main regularities in the development of the theory of banking regulation have been identified.

In order to formalize the content analysis of research conducted by the scientific research community on banking regulation, 2006 scientific publications, indexed by the Scopus scientific database during 1910–2021, were selected.[1] The selection of relevant publications was made on the basis of keywords, and the basic concept was chosen "banking regulation", which is a common English-language analogue of the domestic concept of "bank regulation". The results of this block of bibliometric analysis are presented on *Fig. 1*. According to its results, a map of relationship of the concept of "bank regulation" with other categories was formed, which allowed to allocate five clusters of scientific research: they are indicated in blue, yellow, green, red and purple on *Fig. 1*.

In addition, should also be noted that the larger diameter of the circle means a greater frequency of mentioning the relevant concept as a keyword next to the banking regulation in scientific articles indexed by Scopus scientific database over more than one century. Generalization of the results of informational-contextual block of bibliometric analysis has revealed that the main bulk of scientific research is focused on identifying the relationships of banking regulation and other types of policies (monetary and macroprudential), financial stability and systemic risk (red cluster), financial crisis (yellow), methodical recommendations of the Basel agreements (blue), market environment banking activities (green), financial integration (purple). In addition, it should be noted that there are intersection and relationship between the identified clusters. Thus, the stability of the financial system and, consequently, the probability of financial crisis depends on the implementation of requirements to regulatory capital, level of financial leverage and liquidity, developed by BCBS to improve the quality of risk management. The closeness of the relationship of concepts is also analyzed on the basis of the distance between circles, which characterizes the frequency of co-occurrence of concepts.

In the context of expanding the evolution-time perspective of this research it is advisable to analyze the results of context-time block of bibliometric analysis, Within the framework of which the main substantive determinants of research on banking regulation are ranked by temporal basis for the period 2007–2020.[2] In *Fig. 2* the gradient changes from purple (the earliest publications indexed by the Scopus scientific database) to yellow (modern works).

Analysis of the context-time research cluster on banking regulation revealed five stages during which the main focuses in this area changed. Thus, scientists considered the relationship of financial liberalization, in particular deregulation of banking activities, with the improvement of banking regulation system in 2007–2009; researchers focused on identifying the effects of the financial crisis due to the weakening of banking regulation and supervision in 2010–2012; the scientific work on the implementation of Basel III [in particular, individual requirements (regulations) of regulatory capital, leverage and liquidity] in response to the weaknesses of banking regulation revealed by the financial crisis came to the fore in 2013–2015, while in 2016–2018 the attention of scientists was focused on macroprudential regulation and issues of shadow banking sector; the research vector of scientists has changed towards the relationship of banking regulation, financial innovation and financial inclusion in 2019–2020.

In the context of the continuation of the temporal perspective of bibliometric analysis of studies on banking regulation,

[1] Scopus. 2021. Documents search. URL: https://www.scopus.com/search/form.uri?display=basic#basic

[2] Spectrum of analyses reduced compared to the contextual block of bibliometric analysis due to the small number of relevant research during the period 1910–2006 and 2021.

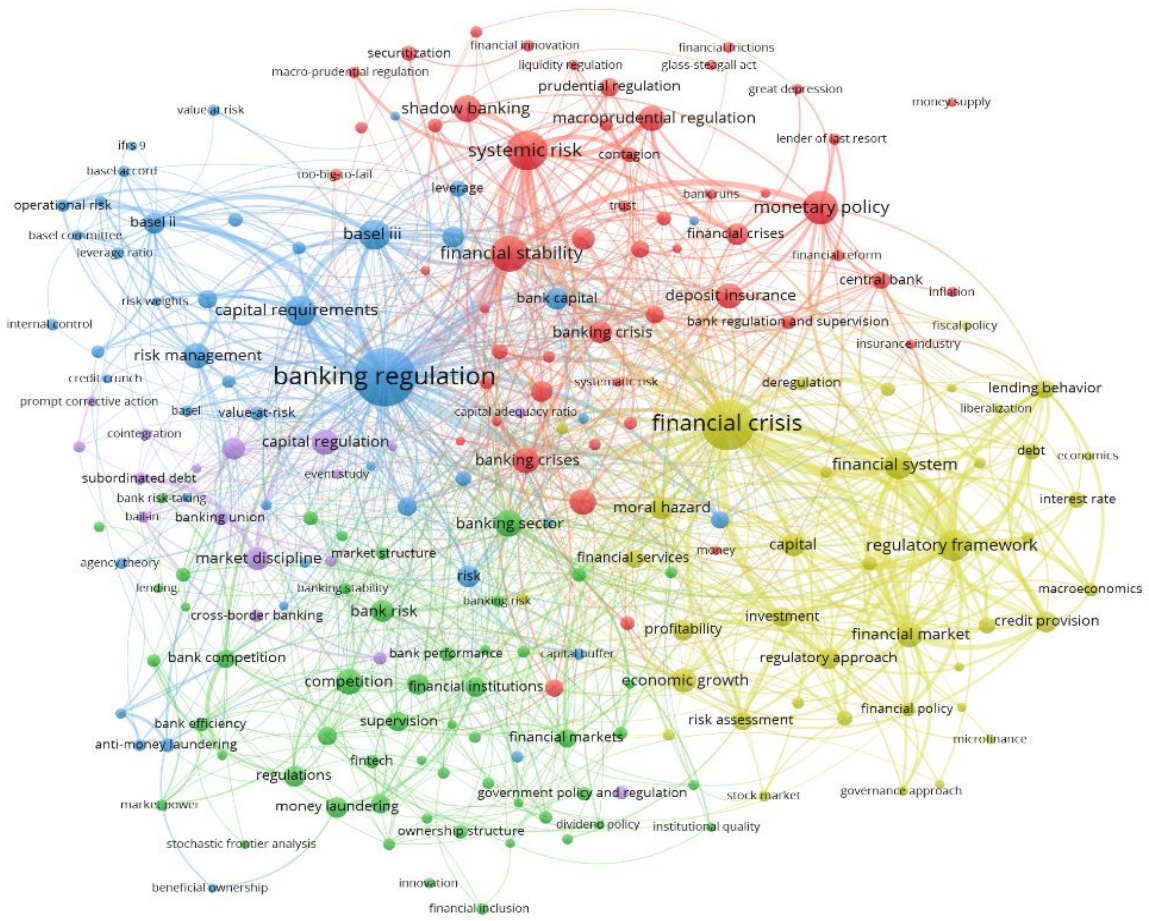

Fig. 1. **Banking regulation relationship to other concepts from 1910 to 2021**

Source: built by the author using VOSviewer v.1.6.10 based on Scopus data.

it is also advisable to carry out the spatial decomposition shown on *Fig. 3*.

As a result of the spatial and temporal bibliometric analysis, it is established that intensification of research on banking regulation occurs in the world during 2008–2020 within six consecutive time ranges, each with its own geographical centers. In general, the following pattern can be noted: earlier researches of various aspects of banking regulation have been conducted in industrialized countries with high per capita GDP, In the second half of time period under study, their geography expands to less economically developed countries.

However, some scientific interest is not only the spatial and temporal analysis of publication activity on banking regulation, but also the analysis of the geographical relationships in this field, which are presented at *Fig. 4*.

Based on the results of spatial clustering, five groups of countries were identified, the researchers of which have common publications on banking regulation. The first two clusters are intercontinental with a predominance of countries in the same subregion. For example, the first cluster has 19 countries. It covers the Northern (Mexico, Canada, USA) and Southern (Chile, Colombia, Argentina) subregions of the America, Australia, Oceania (New Zealand), and East (China, including Hong Kong, Japan, South Korea, Taiwan), South-East (Philippines, Indonesia, Singapore, Vietnam) and West (Jordan) subregions of Asia. The second largest cluster includes 18 countries with the prevalence of Africa (Egypt, Ghana, Nigeria,

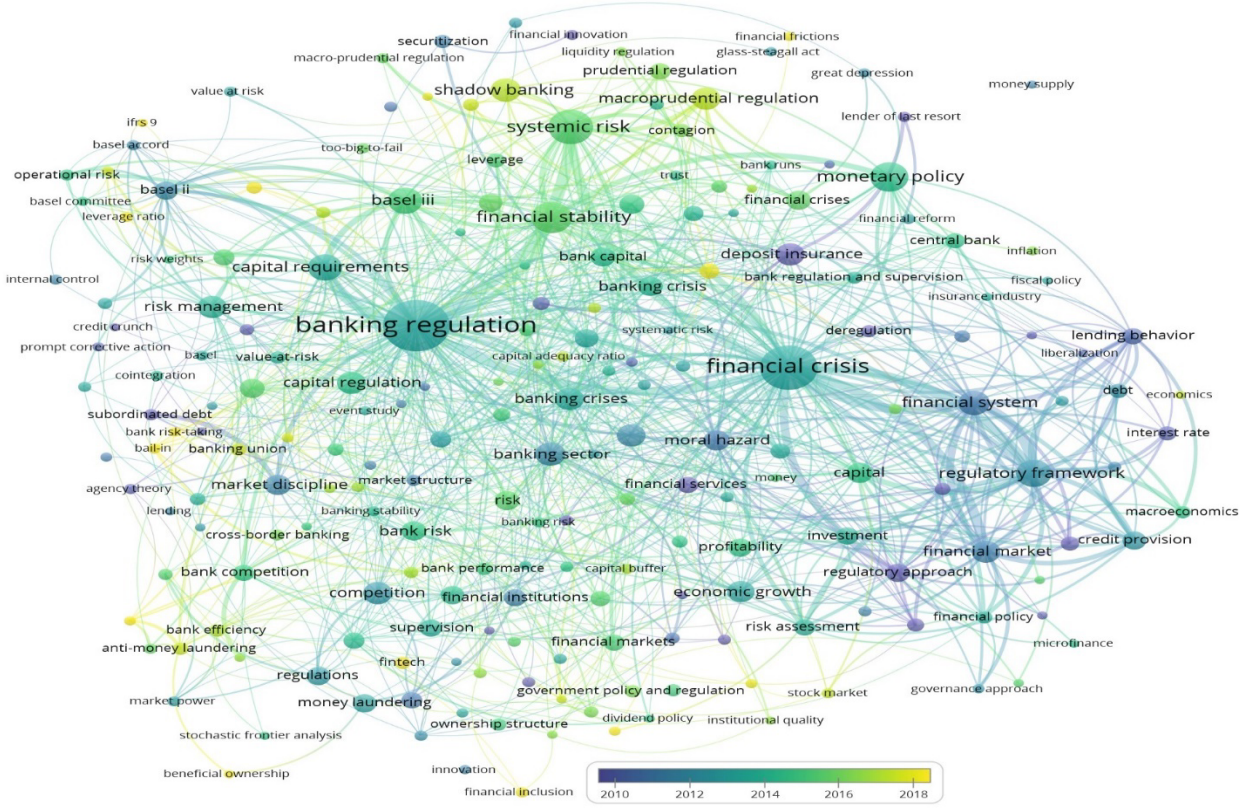

Fig. 2. **A visual map of context-time analysis on banking regulation studies published in 2007–2020 in the Scopus journals**

Source: built by the author using the Scopus journals database.

South Africa, Tunisia), subregions of Western (Belgium, France, Ireland, United Kingdom), Southern (Greece, Italy, Portugal, Spain) and Northern (Norway) Europe, and also Western Asia (Israel, Turkey, UAE). The third cluster consists exclusively of European countries in the three subregions of Europe: Western (Austria, Germany, Luxembourg, Netherlands, Switzerland), Eastern (Czech Republic, Hungary, Romania) and Northern (Denmark, Sweden). The fourth and fifth clusters consist, respectively, of four countries in South Asia (India, Malaysia, Pakistan, Saudi Arabia) and Eastern Europe (Poland, Ukraine, Kazakhstan, Russia). Thus, the analysis showed that there are links between researchers on bank regulation mainly by geographical proximity, but the two clusters also bring together representatives of the scientific community from different continents.

In this context, it should also be noted that out of the total amount of scientific publications indexed by Scopus scientific database, the most relevant work in the period 1910–2021 was recorded in the USA (576 scientific articles), the UK (284), Germany (138), France (116), Italy (102), Australia (74), Spain (69), Canada (59), Switzerland (56), the Netherlands (54), while in other countries the number of publications per period under analysis does not exceed 50 units.

BINARY MODELING: RESEARCH METHODOLOGY

The empirical goal of this research is to identify the impact of bank regulation tools on the probability of a banking crisis. For the construction of the forecasting model of manifestations of the system banking crisis, the method of logistic regression (logit-model) was chosen among the methods of statistical

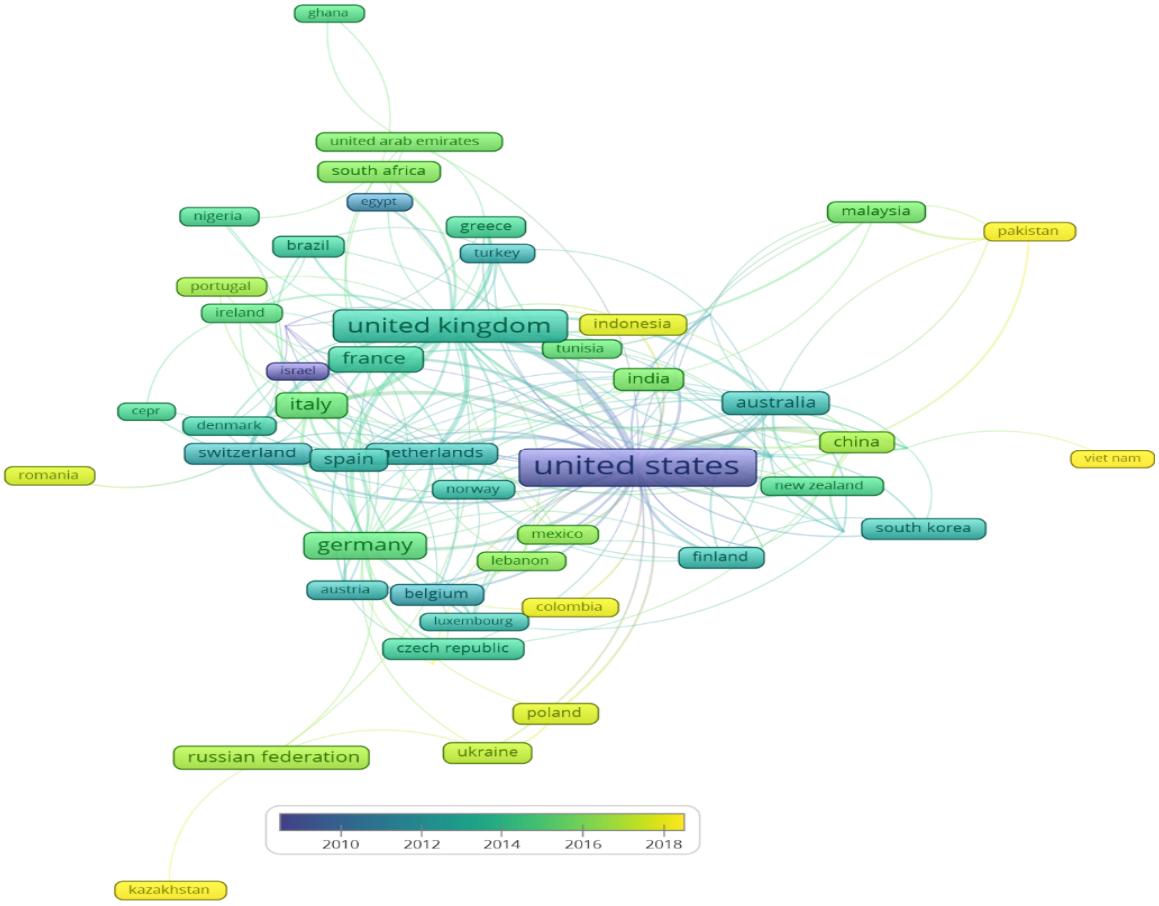

Fig. 3. **A visual map of space-time analysis on banking regulation studies published in 2007–2020 in the Scopus journals**

Source: built by the author using the Scopus journals database.

analysis — the model of binary selection based on the logistic function. Selected scientific and methodological tools allow predicting the probability of some event (in this case, a banking crisis) by the values of a set of features [36–45].

Estimation of total performance, probability of observed results, correspondence and diagnostics of accuracy of constructed logit- and probit-models was carried out using the estimation of logarithm of likelihood (–2LL), *p*-value criterion, classification accuracy matrix, calculated on the basis of a general level of accuracy and more specific misclassification factors, and a curve ROC (Receiver Operating Characteristic).

The diagnosis of accuracy for comparison with other empirical models was conducted using a classification accuracy matrix. Based on the classification accuracy matrix, a general degree of accuracy, a type I error and a type II error (specific factors of the misclassification) were determined.

The overall level of accuracy helps analyze the ability of built logit-models to correctly classify the time of stability and the time of system banking crisis (*Table 1*). The following formula shall be used for its calculation:

$$\textit{Overall level of accuracy} = \textit{(Correctly classified time / Total number of observations)} * 100 = ((TP + TN) / (TP + FP + TN + FN)) * 100. \quad (1)$$

Type I error estimates the number of observations representing a system banking crisis that have been incorrectly classified, i.e. times of stability. Therefore, it is calculated as

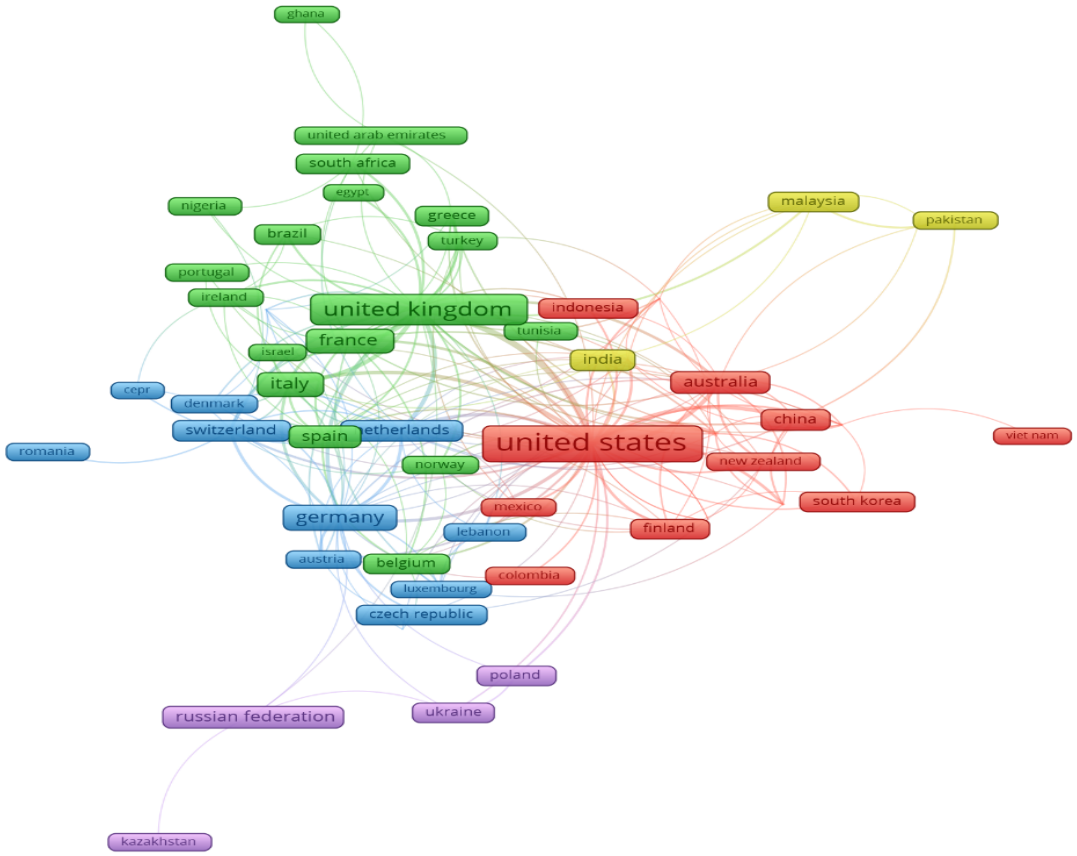

Fig. 4. **A visual map of scientists' co-authorship (criterion — the country specified in the affiliation), whose joint publications on banking regulation were indexed by the Scopus journals database in 1910–2021**

Source: built by the author using the Scopus journals database.

the ratio of false negative results to the sum of true positive and false negative results:

$$Type\ I\ Error = (FN / (TP + FN)) * 100. \quad (2)$$

By contrast, a type II error estimates the number of observations representing the time of stability, which has been classified as the time of the system banking crisis. Thus, a type II error is calculated as the ratio of false positive results to the sum of false positive and true negative results:

$$Type\ II\ Error = (FP / (FP + TN)) * 100. \quad (3)$$

Another informative and generalizing metric used in the study is the area below the error curve (ROC). This graphical curve ROC is based on the estimated degree of accuracy, type I and type II errors. The ROC curve and area below it (AUC) was used to estimate diagnostic accuracy.

The sample period for this research is 20 years (1998–2017). Annual data were collected from OECD, Eurostat and World Bank reports. Logit- and probit-regressions used for data processing and analysis were performed in STATISTICA computer system. The research includes 10 European countries with banking systems characterized by periods of stability and volatility (crisis), in particular: Austria, Belgium, Hungary, Greece, Denmark, Spain, Latvia, Moldova, Ukraine, France. The number of complete observations for the whole period of the research was 184, of which 46 (97.87% of the total) observations characterized crisis periods and 138 (90.19% of the total) observations characterized periods of stability of banking systems of European countries.

Table 1

Classification accuracy matrix for models assessment

Observed events	Predicted events	
	Time of stability (*T*)	**Time of crisis (*F*)**
Time of stability (*T*)	True positive (*TP*)	False positive (*FP*)
Time of crisis (*F*)	False negative (*FN*)	True negative (*TN*)

Source: compiled by the author.

According to previous research, for the goal of this research, the process of selecting variables is based on indicators that best reflect bank regulation and those that clearly symbolize a systemic banking crisis in the country. As a basis in models of the probability of a system banking crisis, the original data set was generated from 25 independent variables, which were considered relevant in previous researches. After solving the multicollinearity problem, the final set of variables consists of four (narrow, Model I) and seven (extended, Model II) independent variables in two categories. The first group of indicators characterizes the instruments of bank regulation, they are represented by the following indicators: bank capital to total assets,%; bank nonperforming loans to gross loans,%; bank regulatory capital to risk-weighted assets,%; Z-score of bank default probability. These indicators reflect banking regulation in the country according to BCBS requirements regarding capital adequacy, asset quality, level of risks accepted by the bank. In addition, the logit-model integrates Z-score of probability of bank default, calculated on the basis of non-consolidated data on individual banks from Bankscope (Bureau van Dijk — BvD), since this estimate relates the buffers (capitalization and profitability) of individual commercial banks to the volatility (instability) of these incomes.

The second set of indicators, which is included in the extended model type II (Model II), characterizes macroeconomic factors and monetary policy factors, in particular: real GDP growth rate (%), real interest rate (%), inflation (%). These indicators describe commonly accepted monetary policy objectives and instruments.

Binary regressions were implemented according to model specifications, namely: logit and probit to test the hypothesis regarding the ability of banking regulation to prevent the probability of a banking crisis. In this type of model, dependent variables must be recoded as binary variables that can only take two types of values. In this research, the dependent variable is a dummy variable of the banking crisis (Banking Crisis Dummy), developed by experts of the IMF [46] based on expert-criterion definition. Therefore, this variable assumes a value of 1 in case of system banking crisis (time of crisis) or 0 — in the event of non-affection (time of stabilization).

When establishing the fact of the banking crisis as a system in different countries, IMF experts used criteria that reflect the signs of significant turbulence of the banking system, including information on the losses of the banking system, the number of financial and credit institutions liquidated and the degree of intervention of the financial regulator in response to the scale of losses of the banking sector.

RESULTS OF EMPIRICAL RESEARCH

In the course of this study, two types of models with two types of data sets (narrow and extended) were developed and tested using logit- and probit-regressions. Given that the developed probit-regression models

were statistically insignificant for all model performance indicators, the subsequent interpretation of the results will be carried out only for logit-regression models. Results of logit-modeling of probability of system banking crisis are presented in *Table 2*.

Results of binary modeling show the importance of banking regulation for forecasting the probability of a systemic banking crisis in European countries. According to the first type of model, the ratio of bank capital to total assets has a negative relationship with the probability of a systemic banking crisis in these countries. Thus, faster growth of bank capital over aggregate assets minimizes the probability of a banking crisis, as it is a critical and necessary element of economic self-sufficiency, profitability and financial sustainability of the banking system.

At the same time, the deterioration in the asset quality of the European banking system as the ratio of non-performing loans to total loans increases the probability of a systemic banking crisis. This fact confirms the hypothesis that aggressive credit policy and inadequate risk assessment, expressed by increasing the share of non-performing loans, not only worsens the profitability of banking activities, but also negatively affects the financial sustainability of the banking system as a whole. The negative effect is increased when there is insufficient supply for overdue and impaired loans, as well as inadequate formed credit risk reserves.

Increased equity to total risk-weighted assets reduces the probability of a banking crisis. This bank regulatory tool provides a buffer to protect the banking system from peak losses that exceed expected credit losses. In this context, the role of the Basel agreements in stabilizing the entire financial system and increasing bank capital is clearly evident.

According to early research, the coefficient for the Z-score of bank default probability assumed a negative value. This feedback on the probability of a systemic banking crisis can be explained by the economic interpretation of the Z-score of the probability of bank default. It shows how much of the standard deviation should be reduced by the current return value so that losses to the bank or the banking system as a whole, which are the result of negative factors, can exceed its equity capital. Thus, reducing the probability of insolvency of the European banking system, namely, the probability that aggregate assets will be lower than the value of total liabilities, reduces the probability of a banking crisis.

According to the assessment of the statistical significance of models (Model I — narrow and Model II — expanded) use of macroeconomic variables and monetary policy factors potentially allows to improve the predictive quality of the model of probability of system banking crisis. This conclusion is consistent with previous studies [47] which identified the inadequacy of traditional methods aimed at analyzing the bank's capital adequacy, liquidity and compliance with the Basel Committee on Banking Supervision (BCBS) compulsory economic standards.

Results of logit-modeling, given in *Table 2*, show importance of macroeconomic variables in forecasting probability of system banking crisis. For example, real GDP growth is significant with negative coefficient sign. This negative correlation shows that the growth of the economy is accompanied by an increase in financial welfare of all economic agents, which, accordingly, is reflected in the growth of liquidity of the banking system, a decrease in the number and volume of non-performing loans and, as a result, reduces the probability of systemic banking crises in European countries.

Empirical results of *Table 2* show that the monetary policy variable — the real interest rate — is statistically significant, and has an expected sign. Its negative ratio indicates that monetary tightening is with reduced chances of systemic banking crisis. This result makes sense, because soft monetary policy can lead

Table 2

Estimated logit probability model of systemic banking crisis occurrence

Variables	Model I (narrow)	Model II (extended)
b_0	4.31840	1.14853
Bank capital to total assets (%)	–0.39922	–0.87796
Problem loans to total loans (%)	0.26522	0.44900
Equity to total risk-weighted assets (%)	–0.15592	–0.06527
Z-score of bank default probability	–0.15047	–0.06052
Real GDP growth (%)		–0.53262
Real interest rate (%)		–0.05915
Inflation (%)		0.154
Statistical relevance of the model		
Chi2	*23.42135*	*39.87975*
p-value	*0.00010*	*0.00000*
Final loss	*13.26965*	*5.04040*
*–2*Log-likelihood*	*26.53930*	*10.08080*

Source: compiled by the author.

to a credit bubble that often leads banking crises.

The last independent variable, which is at the same time a factor describing the macroeconomic situation in the country, also reflects the monetary policy target of ensuring the stability of the national unit — inflation. Calculated inflation rate is statistically significant at 5% and positive. Contrary to the view of some researchers that borrowers benefit indirectly from rising inflation as their debt burden is reduced, the conducted study records a significant positive impact of inflation growth on the probability of the banking crisis. This is also consistent with economic theory, as rising inflation creates instability in the economy, a fall in real incomes of all financial market actors, the propensity of households to borrow, respectively — growth of non-performing loans in commercial banks' loan portfolios, which increases the likelihood of systemic banking crisis. Thus, monitoring and controlling inflation should be the main objective of monetary and fiscal policy.

CLASSIFICATION QUALITY METRICS

Table 3 presents the accuracy of the classification of models that predict the probability of a systemic banking crisis in European countries, both for narrow (Model I) and extended (Model II) datasets.

As seen from *Table 3*, calculated logit-model I (narrow) classifies the stability time with an accuracy of 95.65% and the system banking crisis with an accuracy level of 10.87%. The overall accuracy level of the evaluated Model I (narrow) is 74.46%. However, according to *Table 2, 3*, the inclusion of additional macroeconomic and monetary factors in

the model improves not only the predictive quality of the probability model of a systemic banking crisis, but also the accuracy of the classification of the model. Thus, Model II (extended) gives a much higher overall level of accuracy, which is 86.96%, and therefore has a higher level of classification accuracy, both for periods of stability and periods of crisis, than Model I (narrow). Model II (extended) predicts stability time with an accuracy of 97.11%, which is 1.46% more than Model I (narrow). The feature of the Model II (extended) is also its better accuracy of forecasting the time of the banking crisis. Thus, it is able to predict the probability of a systemic banking crisis with an accuracy of 56.52%, which is 5 times more accurate than the previous model.

In general, the logit-models, unlike the probit-regressions, gave consistent results for all datasets. However, a comparison of the overall accuracy indicates that the level of accuracy of the assessed Model II (extended) is higher than that of the assessed Model I (narrow). This conclusion shows that Model II (extended) can be used to predict the probability of a systemic banking crisis in European countries.

Table 4 presents results for more specific misclassification factors. The data show a higher accuracy of the Model II classification (extended), as the probability of correct classification is highest (86.84%) compared to 60.88% of Model I (narrow). According to the results, when applying the logit-model to an extended data set, there is only 12.99% false negative classification and 13.33% false positive classification (lowest values among all models and datasets). Therefore, the highest values of true positive cases [sensitivity (Sensitivity (TPR) is 87.01] and true negative cases [specificity (TNR) is 86.67] which have been correctly identified by Model II (extended).

In addition to other tools for predicting the accuracy of the proposed models, curves ROC were constructed. Graphic illustration of the compromise between sensitivity and specificity of the classification table constructed for each data set (narrow and extended) is presented at *Fig. 5*.

As seen from *Fig. 5*, the area below the ROC curve representing the accuracy metric of the classification of the various cut-off points, for the extended dataset of Model II is larger than for Model I, which is represented exclusively by banking regulatory indicators. This visual comparison of ROC curves leads to the conclusion that Model II (extended) is the most effective for predicting the probability of a systemic banking crisis.

CONCLUSIONS AND SUGGESTION FOR FURTHER RESEARCH

Following the 2008 financial crisis, BCBS started discussing new regulatory approaches to address systemic risk and reduce the probability of further financial crises. New set of standards released by BCBS in 2010–2011, introduced a separate set of banking regulation tools. Since then, financial regulators in the EU and around the world have been actively working on its implementation. However, although bank regulation tools have become an accepted part of the financial regulation system, there is still a lack of systematic data that would allow them to study their effectiveness. As a result, assessment of effects of bank regulation measures on the probability of a banking crisis has become one of the most difficult challenges currently facing regulators.

Theoretical bases of revealing regularities in development of the theory of banking regulation and system banking crisis were developed on the basis of bibliometric analysis (VOSviewer v.1.6.10). This analysis allowed to identify and describe content and contextual (causes and periods of change of interest in banking regulation, dominant directions of scientific research in this area and cross-sectoral research), as well as evolutionary-temporal (in the coordinate system "period of research — contextual orientation — spatial geography") regularities, to carry out the

Table 3

Classification accuracy for logit models

	Observed events	Predicted events		Classification accuracy, %
		Stability time (0)	Crisis time (1)	
Model I (narrow)	Stability time (0)	132	6	95.65
	Crisis time (1)	41	5	10.87
Overall level of accuracy				74.46
Model II (extended)	Stability time (0)	134	4	97.11
	Crisis time (1)	20	26	56.52
Overall level of accuracy				86.96

Source: compiled by the author.

Table 4

More specific misclassification rates for logit estimated models

	AUC	Sensitivity — TPR	False negative rate — FNR [1]	Specificity — TNR	False positive rate — FPR [2]
Model I (narrow)	60.88	76.30	23.70	45.45	54.55
Model II (extended)	86.84	87.01	12.99	86.67	13.33

Source: compiled by the author.

Note: [1] False negative rate (FNR), corresponds to Type I Error; [2] False positive rate (FPR), corresponds to Type II Error.

clustering of research works regarding the affiliation of scientists.

The empirical objective of the study was to identify the impact of bank regulation on the probability of a banking crisis. The following conclusions can be done from the analysis. Bank regulation tools are important in predicting the probability of a systemic banking crisis in European countries. However, a model containing only indicators that characterize government interventions in banking is able to correctly classify stability times with an accuracy of 95.65%, and a systemic banking crisis — with an accuracy of only 10.87%. Ratio of bank capital to total assets, equity to total assets weighted for risk and Z-score of bank default probability, the results of binary modelling of logistic regression are significant with negative coefficients. This indicates that trend of an increase in these indicators reduces the probability of a systemic banking crisis by providing a buffer to protect the banking system from peak losses that exceed the possible level of credit losses.

In this context, the role of the Basel agreements in stabilizing the entire financial system and increasing bank capital is clearly evident. At the same time, the deterioration in the asset quality of the European banking system as the ratio of non-performing loans to total loans increases the probability of a systemic banking crisis. This fact confirms

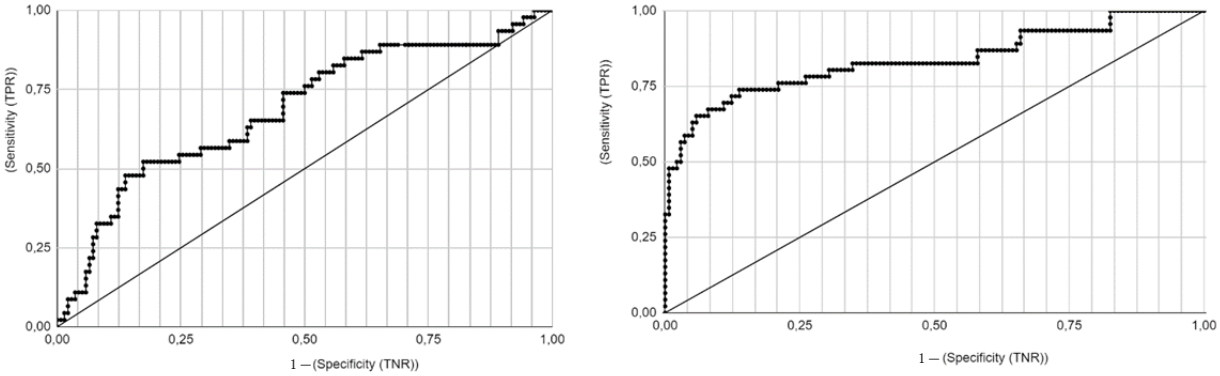

Fig. 5. **ROC curves graphical illustration for (a) Model I (narrow) and (в) Model II (extended)**

Source: compiled by the author.

the hypothesis that aggressive credit policy and inadequate risk assessment, expressed by increasing the share of non-performing loans, not only worsen the profitability of banking activities, but also negatively affect the financial sustainability of the banking system as a whole.

Results of logit-modeling also emphasize the importance of macroeconomic and monetary factors, neglect of which leads to vulnerability of banking institutions and, as a consequence, to banking crises. The inclusion of additional macroeconomic and monetary factors in the model improved not only the predictive quality of the model of the probability of a system banking crisis, but also the accuracy of the classification of the model (accuracy of classification of stability of the banking system and crisis periods increased, respectively, by 1.46 and 44.65%).

Real GDP growth and falling inflation contribute to the economic stability of European countries and are adequately reflected in the growth of the financial well-being of all economic agents and the liquidity of the banking system, and reducing the number and volume of non-performing loans, which reduces the probability of systemic banking crises in European countries also. At the same time, tightening of monetary policy by regulating the real interest rate minimizes the risk of a credit bubble, which often leads to banking crises.

Further research should, in our view, be directed to an in-depth study of additional instruments of bank regulation, in particular, in the direction of the impact of capital preservation buffers, systemic risk protection, systemic importance buffer and counter-cyclical buffer, the probability of a systemic banking crisis, including the "lag" of some indicators. Another direction of promising development could be to address the issue of complementary impact of different types of financial policies in order to minimize potential threats in the financial sector of the economy and, reducing the probability of a banking crisis in European countries.

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